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(54) Liquid spraying apparatus

(57) A liquid sprayer 1 is enclosed in a case 4 with at least one window 5. A screen 7 overlaps a portion of the flow area of the window 5 and its edge 8 restricts the flow area. The edge 8 has a curvilinear configuration determining the liquid distribution density on the surface being treated.

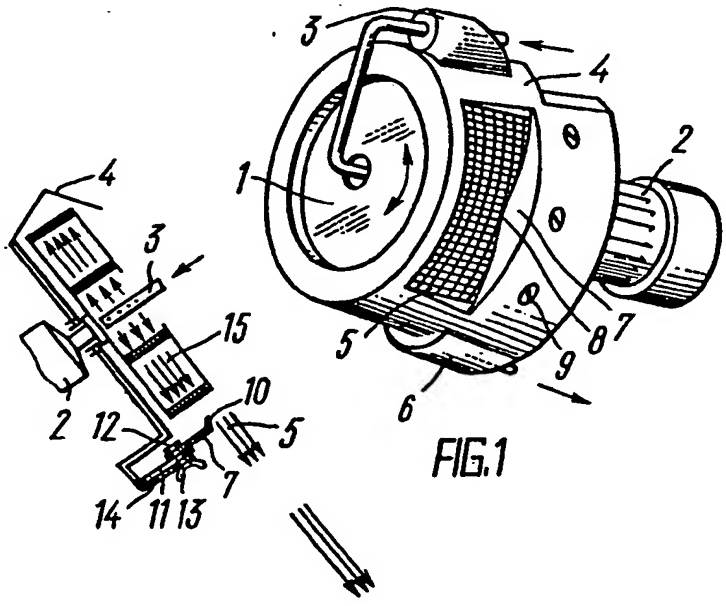

FIG.1

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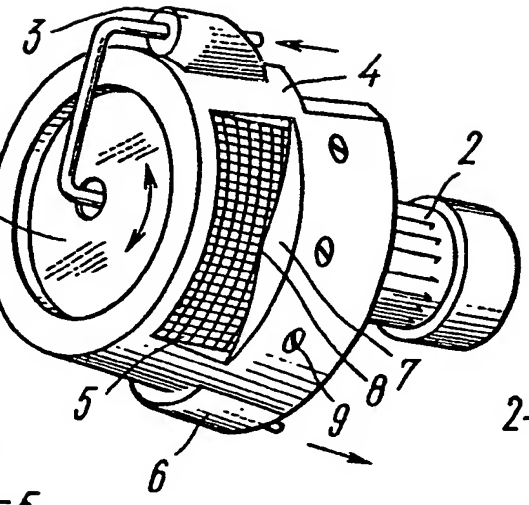
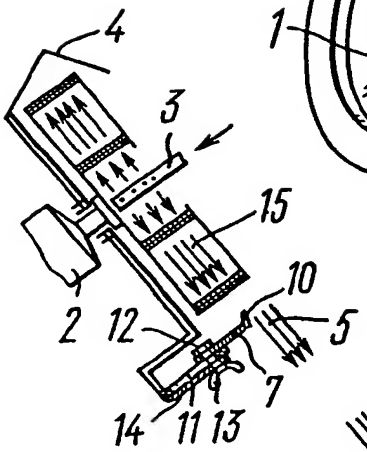


FIG.1



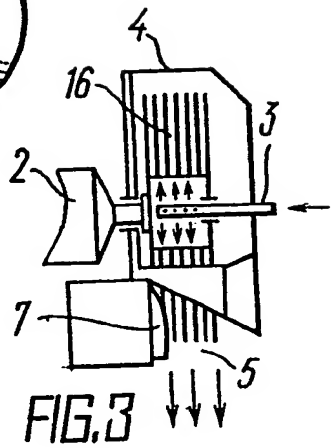


FIG.3

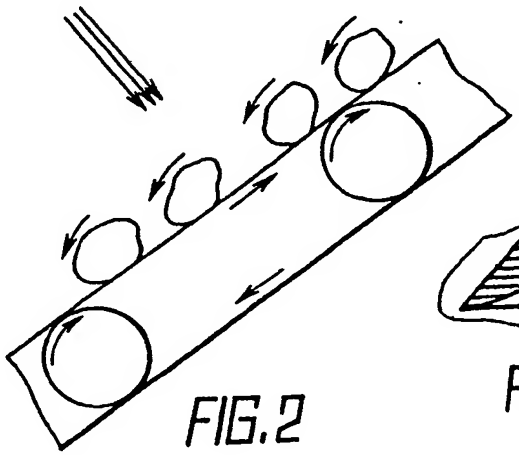


FIG.2

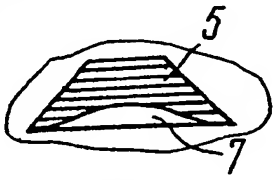


FIG.4

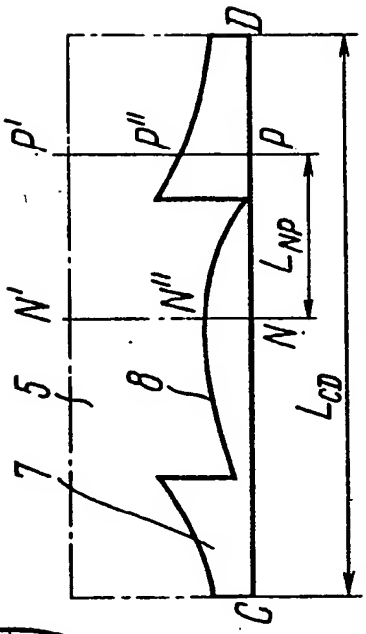


FIG.6

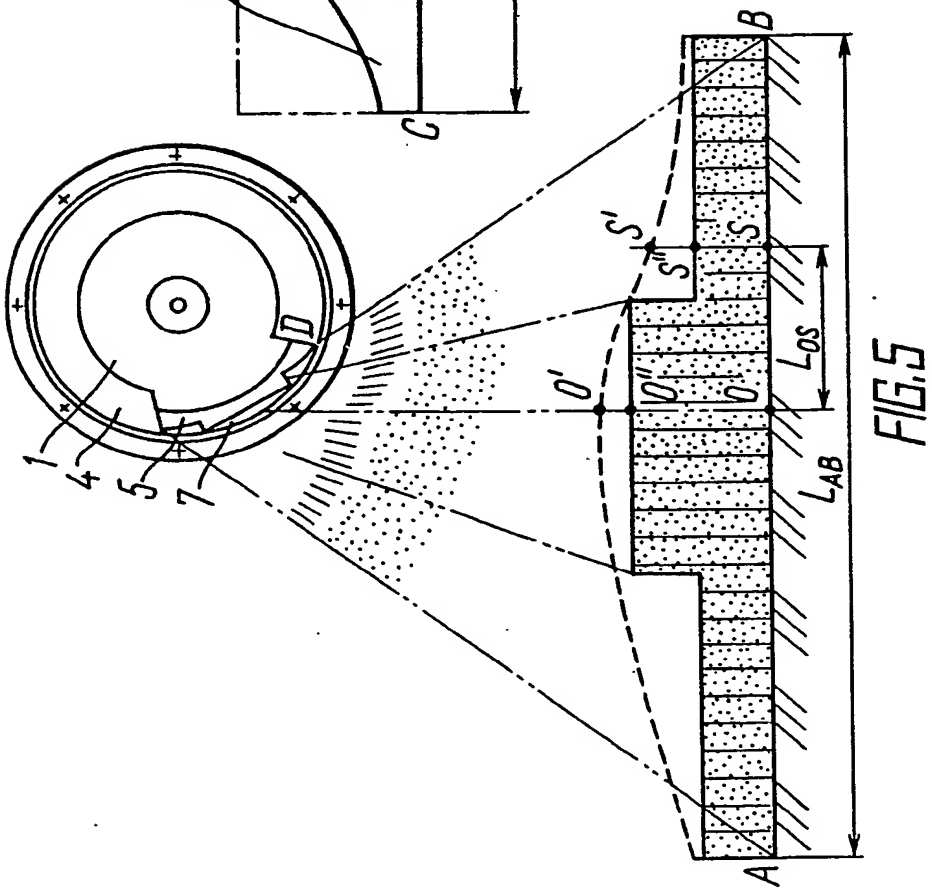


FIG.5

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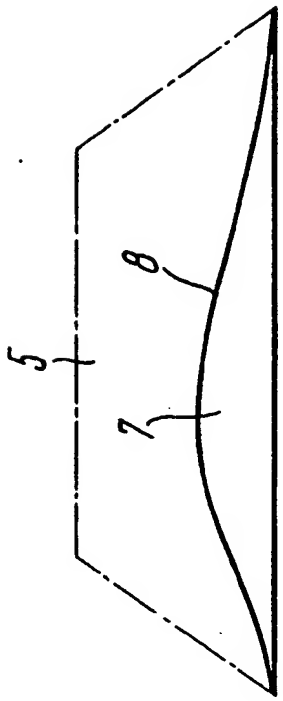

FIG.8

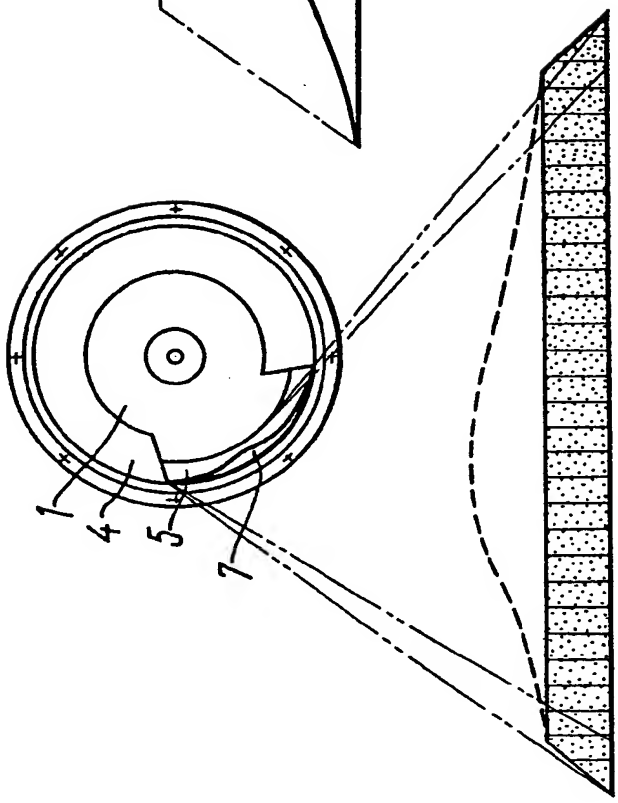

FIG.7

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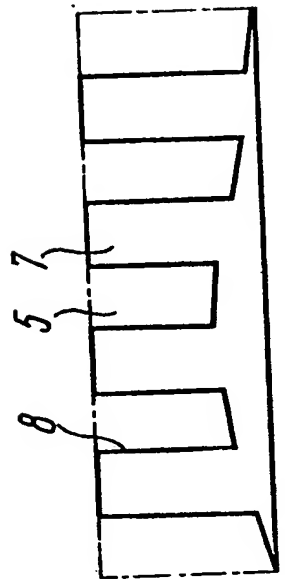

FIG.12

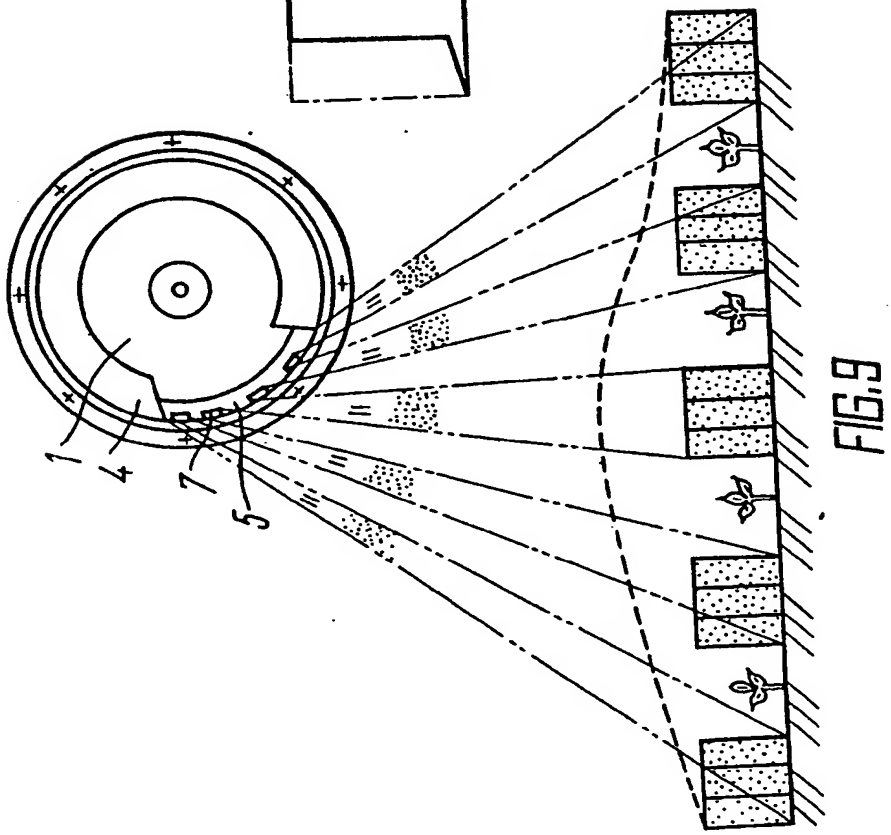

FIG.9

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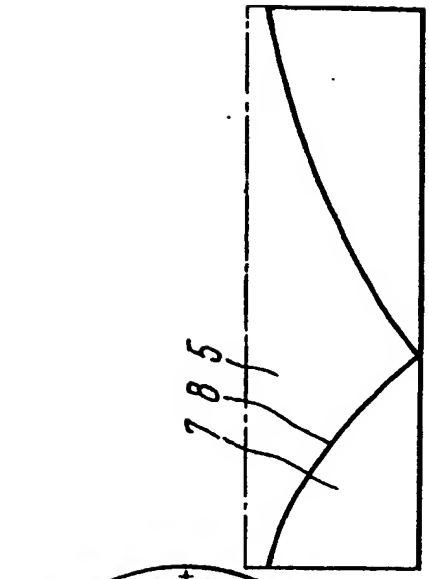

FIG.13

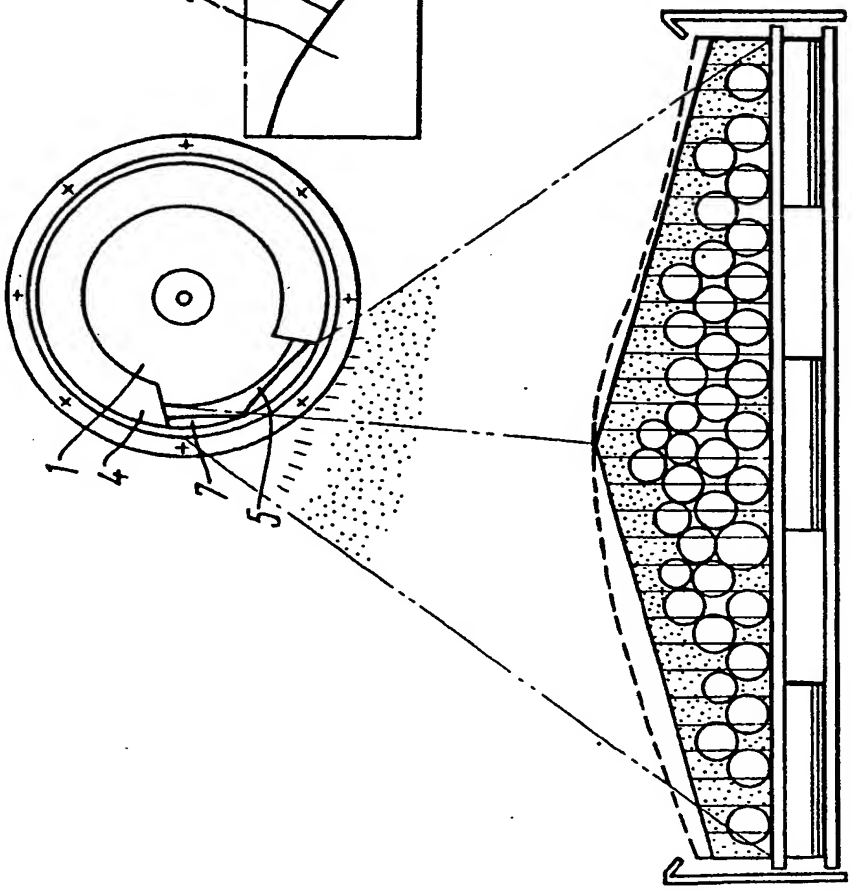

FIG.10

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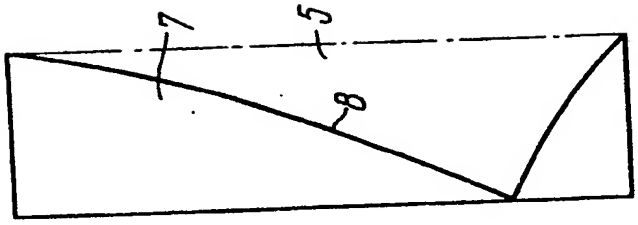

FIG.14

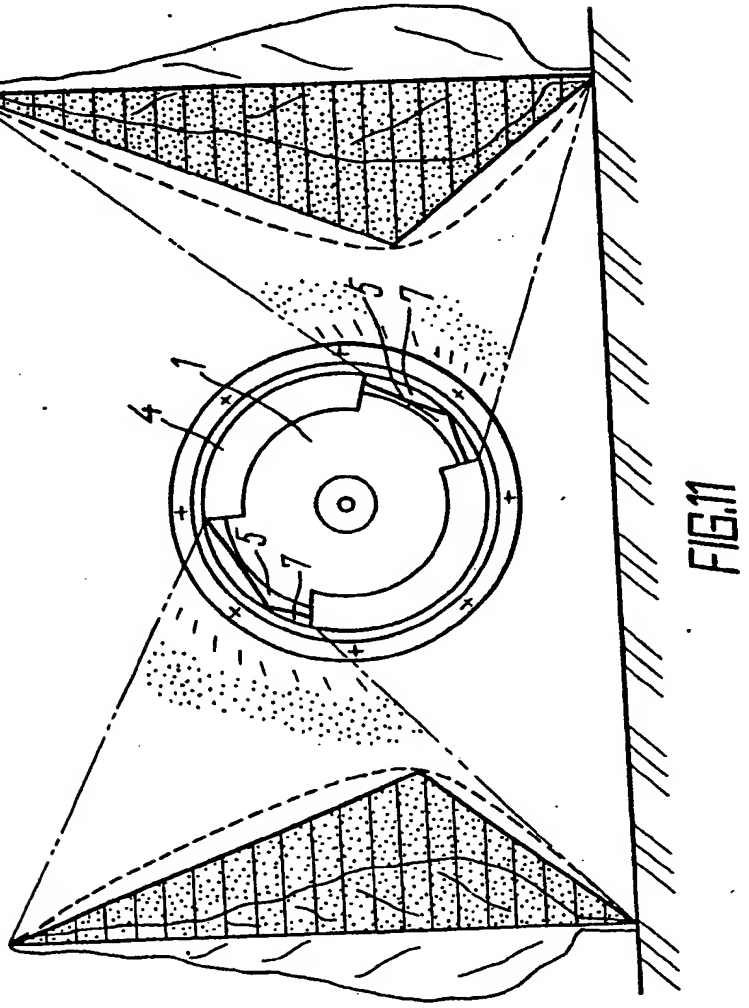

FIG.11

SPECIFICATION

Liquid spraying apparatus

The present invention relates to apparatuses for spraying liquids and suspensions, which may be used, for example, in machines for protection of plants against vermin, diseases, and weeds, e.g. sprayers and treaters.

Widely used in agricultural engineering are liquid spraying apparatuses with a narrow spray cone, including sprayers, rotating on a drive shaft at a high speed, in the form of various spraying disks, conical cups, drums, and cylinders enclosed in protective cases with windows facing the surface being treated, and with devices for collecting and draining the liquid deposited on the walls thereof (cf. USSR Inventor's Certificates No. 923,489 and No. 1,149,914, Int. Cl³. A01M 7/00).

In the process of operation the working liquid is fed to the central part of the rotating sprayer, is set rotating by the action of the frictional force and, acted upon by the centrifugal force, spreads in a thin film towards the periphery thereof, where it breaks away from the edge and disperses into drops, whose size depends mainly on the parameters and make of the sprayer (its diameter or the diameters of its spraying elements, properties of the material it is made of, roughness of working surfaces), its rotation speed and physico-mechanical properties of the liquid being sprayed, and whose mechanical trajectories at the initial moment are rectilinear, approximating the lines tangent to the circumference of the spraying elements.

Atomized liquid drops settle on the inner walls of the case and drain off into a receiver, whence the liquid is fed back for recycling. Atomized drops also pass through the window in the case wall, facing the surface being treated, forming a narrow spraying cone directed at the objects subject to treatment.

Such devices in plant protecting machines are generally arranged so that the sprayers rotate in a horizontal plane.

However, with the horizontal arrangement of spraying devices of the booms of field crop sprayers the liquid sprayed by each device and the machine as a whole tends to be distributed non-uniformly on the surface being treated; besides, a considerable amount of the liquid is blown away by the wind, which results in excessive consumption of costly preparations, environmental pollution, and worsening of the operator's working conditions.

The prior art also includes a so-called Girojet spraying apparatus incorporated in a TG-412 crop sprayer manufactured by the French Tecnoma firm (cf. French Patent No. 2,497,439, A01M 7/00, 1982).

The Girojet apparatus comprises a sprayer made in the form of a spraying disk rotatable by an electric motor through a magnetic coupling and a drive shaft, with the central part thereof associated with a device to feed a working liquid, enclosed in a protective case with a window made in the wall thereof facing the surface being treated, and associated with a device for collecting and draining the liquid.

A major advantage of the sprayer provided with the above spraying apparatuses, which makes it superior to other similar machines, is a non-traditional arrangement of the disk sprayers on the boom. The sprayers in the given case rotate in a vertical plane, and the windows occupy such a position relative to the ground that the atomized drops of the liquid fall onto the objects being treated along the shortest trajectories.

Owing to such arrangement of the sprayers in the spraying apparatus the TG-412 sprayer has a number of advantages, e.g. smaller drift of the atomized preparation by the wind due to shorter trajectories along which the drops of liquid travel, the possibility of utilizing not only gravitational but also centrifugal forces for settling them, and a better distribution of the preparation of the leaf surfaces of plants, because inclined trajectories facilitate penetration of the preparation inside the plane and permit treatment of the leaf underside.

However, the spraying apparatus just described fails to ensure uniform distribution of liquid on the surface being treated.

The diagram of density of liquid distribution on the surface being treated in the event of the foregoing spraying apparatus is a curvilinear figure in the form of a curvilinear trapezium with a hump under the sprayer.

Such a non-uniform distribution of liquid results in a poor quality of treatment and excessive consumption of the preparation, because an excessive amount of the preparation falls onto the objects nearest to the spraying apparatus, which has an oppressive effect on the plants and gives rise to environmental pollution; on the other hand, the farther the objects, the smaller amount of the preparation they receive, which reduces the effectiveness of treatment.

On the whole, such a non-uniform density diagram in the event of the foregoing apparatus preconditions a low quality of plant treatment.

Furthermore, many situations necessitate spraying with a preset liquid distribution on the surface being treated, which cannot be attained through the use of the apparatus described

above.

The foregoing apparatus is also characterized in that the dispersivity (i.e. the size) of the drops being atomized varies with the variation of the working liquid consumption rates.

Depending on the crops, their age, the degree to which they are affected by vermin and diseases, and the physico-mechanical and toxic properties of the preparation, the liquid consumption rates may vary considerably. For instance, in the event of superlow-volume sprayers they may fluctuate within 1 to 5 litres per hectare, and with low-volume sprayers the rates may vary from 75 to 300 litres per hectare.

Variation of the amount of the working liquid supplied to the sprayer per unit time entails a corresponding change in the anti-torque moment on the drive shaft, which is conductive to a change in the sprayer rotation speed and, consequently, in the range of particle dimensions.

The optimal size of drops fixed for one of the sprayer operating modes varies with the variation of the liquid consumption rate, which reduces the effectiveness of the treatment, for a lower consumption rate will result in smaller dimensions of the preparation drops and greater drift thereof, whereas a higher consumption rate brings about larger dimensions of the drops and a smaller number thereof per unit of the surface being treated.

What is desired is a liquid spraying apparatus which would permit uniform or preset distribution of liquid on the surface being treated with a view to increasing the crop capacity and economy of the preparation. Preferably it would also allow liquid consumption rates to be controlled at a constant dispersivity of the liquid.

The present invention provides liquid spraying apparatus comprising a liquid sprayer to which a liquid is to be fed, the sprayer being enclosed in a case having at least one window through which the spray produced by the sprayer is to escape towards a surface to be treated, a screen-overlapping part of the window and having a curvilinear edge delimiting the active flow area of the window.

Preferably the sprayer is mounted on a drive shaft, with a central part thereof associated with a device to feed a working liquid, enclosed in a case with at least one window made in the wall thereof facing the surface being treated, and associated with a liquid draining device, the edge restricting the flow area has a cuvilinear configuration adequate to that of the diagram of density of liquid distribution on the surface being treated, obtained from a sprayer without a screen, or a mirror image of the curvilinear configuration adequate to a preset configuration of the diagram of density of liquid distribution on the surface being treated.

The apparatus for example allows the quality and the efficiency of crop treatment and, accordingly, the crop capacity, to be improved and the preparations used for treating the crops to be economized.

Moreover, provision of a set of removable screens of different configurations of curvilinear edges would allow selection of uniform or preset distribution of preparations on the surface being treated, as well as versatility of the apparatus by using it for diverse kinds of treatment.

The apparatus is simple in design and convenient in servicing and operation.

It is expedient for the screen to have a rim on the side of the said edge, bent inside the case, which will prevent large drops from accumulating and, consequently, from running off the edge onto the surface being treated.

To control the liquid consumption rates within a wide range, with the size of the liquid particles remaining unchanged, it is desirable that the screen is made with the possibility of displacement along the axis of the drive shaft and of being subsequently fixed in this position.

To ensure uniform distribution of liquid on the surface being treated, it is practicable that the window flow area (in the absence of the screen) is of a trapezoidal form.

The invention will now be described further, by way of example, with reference to the accompanying drawings, in which:

Figure 1 is a general axonometric view of liquid spraying apparatus;

Figure 2 schematically illustrates the apparatus in use, longitudinal section, revolved;

Figure 3 schematically shows another embodiment of the apparatus;

Figure 4 illustrates a contour of the flow area, with the apparatus formed in the manner shown in Fig. 3;

Figure 5 is a schematic representation of an embodiment of the apparatus, side view, and a corresponding diagram of density of liquid distribution on the surface being treated;

Figure 6 shows the screen which overlaps a portion of the case window flow area represented in Fig. 5;

Figure 7 is a schematic representation of an embodiment of the apparatus, side view, with a different version of the screen and a corresponding diagram of density of liquid distribution on the surface being treated;

Figure 8 illustrates the screen shown in Fig. 7, which overlaps a portion of the case window flow area;

Figures 9, 10, and 11 represent further embodiments of the apparatus, side view, with different versions of the screen and corresponding diagrams of density of liquid distribution on

the surface being treated with different kinds of treatment being used; and

Figures 12, 13, and 14 illustrate the screens shown respectively in Figs. 9, 10, and 11, which overlaps the case window flow area.

The liquid spraying apparatus comprises a sprayer 1 (Fig. 1) mounted on a drive shaft (not shown) rotatable by an electric motor 2. The central part of the liquid sprayer 1 is associated with a liquid feeding device 3 and the sprayer is enclosed in a (non-rotating) case 4 with a window 5 made in the wall thereof facing the surface being treated. This case has a liquid draining device 6. The apparatus is provided with a screen 7 whose working surface overlaps a portion of the flow area of the window 5 and whose edge 8, restricting the flow area of the window 5 (i.e. delimiting the active flow area), has a curvilinear configuration. The screen 7 is installed so as to be capable of displacement along the axis of the drive shaft and of being subsequently fixed in this position.

The screen 7 may be displaced and subsequently fixed by any method, e.g. with the aid of screws 9. Overlapping a portion of the flow area of the window 5 as required, the screen 7 makes it possible to control the liquid consumption rate without affecting the quality of spraying (optimal dispersivity) and while maintaining a preset pattern of the liquid distribution on the surface being treated.

To prevent drops from accumulating on the edge 8 and running off onto the surface being treated, it is desirable for a rim 10 (Fig. 2) of the screen 7 on the side of the edge 8 to be bent into the case 4. Fig. 2 also shows another version of arrangement of the screen 7, with a part of the screen 7 located between the walls of the case 4. One of the walls has slots 11, with bolts 12 rigidly connected with the screen 7 displacing therein. The bolts 12 are fixed at the required height with the aid of wing nuts 13. The nuts 13 press washers 14, preventing the liquid accumulated in the case 4 from flowing out.

It is expedient for the flow area of the window 5 (Fig. 4) to be of a trapezoidal form, which allows a liquid preparation to be uniformly distributed, with several spraying apparatuses working simultaneously in a line, e.g. on field boom sprayers.

It is preferable that the liquid sprayer 1 has an increased width of the spray cone. To this end, it is made in the form of a meshed drum 15 (Fig. 2) or a stack of disks 16 (Fig. 3) or is of any other design ensuring, in the cross-section of a round-shaped spray cone, a width of the liquid drop flow many times exceeding the diameter of the drops being sprayed. This width may vary in the range 5 mm to 250 mm, and may even reach a greater value.

The screen 7 incorporated in the apparatus may be made in the form of a baffle plate, as illustrated in Fig. 5. The edge 8 (Figs. 5 and 6) of the plate has a mirror imaged curvilinear configuration adequate to the preset configuration of the diagram of density of liquid distribution on the surface being treated.

Expressing the curvilinear configuration of the edge 8 of the screen 7 with respect to each kind of spraying in terms of a mathematical formula presents great difficulties, as such a formula must take account of a large number of factors, including: physical and mechanical properties of the working liquid, the environment, structural and kinematic parameters of the sprayer 1 (diameter of the spraying element, material and its surface finish, rotation speed, etc.), elevation and angle of inclination of the spraying apparatus with respect to the surface being treated, working liquid consumption rate, curvature of liquid particle trajectories etc. Therefore, it is advisable that the configuration of the upper curvilinear edge be determined experimentally for each kind of spraying.

An instance of determining and constructing a mirrorimage curvilinear edge 8 of the screen 7 adequate to the preset configuration of the diagram of density of liquid distribution on the surface being treated is presented in Figs. 5 and 6.

Any required diagram of density of liquid distribution on the surface being treated is superimposed on a similar diagram obtained from the proposed apparatus without the screen 7 (shown by the dashed line in Fig. 5), and the scale is determined on the basis of the screen 7. In our case the scale (coefficient of proportional variation of sizes with the distribution diagram transferred onto the screen) will be equal to:

$$M = L_{CD}/L_{AB}, \qquad (1)$$

where

L_{CD} is the length of the arc of the window 5 of the protective case 4;

L_{AB} is the width of the surface being treated by the apparatus.

Let us construct the curvilinear edge of the screen 7, beginning with the centre OO′ of the diagram of the liquid preparation distribution density (Fig. 5), which corresponds to the centre NN′ of the window 5 in Fig. 6 (where the window 5 and the screen 7 are not cylindrically shaped, but developed into a plane surface). In the middle of the width of the surface being treated, the apparatus without screen 7 ensures the preparation distribution density equal to the length of the line segment OO′. However, the specific case requires that the preparation density

to be obtained in this place is equal to the length of the line segment OO". Consequently, surplus preparation O'O" must be held back by the screen 7. Therefore, the requisite height of the screen 7 in the centre of the window 5 will be found from the following relationship:

$$H_{O'O''}/H_{OO'}=h_{NN''}/h_{NN'}, \quad (2)$$

where

$H_{OO'}$ is the height of the diagram of the preparation distribution density in the centre OO' of the width of the surface being treated without the screen 7;

$H_{O'O''}$ is the height of a portion of the diagram of the preparation distribution density in the centre OO' of the width of the surface being treated, which must be cut off by the screen 7;

$h_{NN'}$ is the height of the window 5 of the apparatus;

$h_{NN''}$ is the height of the screen 7 in the centre of the window 5.

Hence,

$$h_{NN''}=H_{O'O''}.h_{NN'}/H_{OO'}. \quad (3)$$

The curvilinear edge 8 of the screen 7 will further be constructed by passing a plane through different places (to the left and right of the centre OO') of the diagram of the preparation density distribution, determining, at the place of section, the requisite relationship between the height of the portion of the diagram cut off by the screen and the overall height of the diagram, and transferring the given relationship onto the screen, with due account of the scale of variation of the distance from the centre. For instance, with the diagram cut by a plane SS' the requisite relationship will be $H_{S'S''}/H_{SS'}$. To transfer the latter onto the screen, it is necessary to determine a corresponding section PP' in Fig. 7, i.e. multiply it by the scale found from Equation (1):

$$L_{NP}=M.L_{OS}=L_{CD}.L_{OS}/L_{AB} \quad (4)$$

where

L_{OS} is the distance of the cutting plane SS' from the centre of the diagram OO';

L_{NP} is the requisite distance from the centre of the window 5 to the place where the latter is cut by the plane PP'.

Hence, the requisite height of the screen 7 at the cut made by the plane PP' will be:

$$h_{PP''}=H_{S'S''}.h_{PP'}/H_{SS'}. \quad (5)$$

Thus, the curvilinear configuration of the edge 8 of the screen 7 overlapping a part of the window 5, obtained in the manner described hereinabove and shown in Fig. 6, will yield the diagram of the preparation distribution of the surface being treated preset in Fig. 5.

The configuration of the edge will take the form of a diminished and mirror imaged configuration of the diagram of the preset density of the preparation distribution; however, it will be distorted somewhat owing to non-uniform distribution of atomized particles on flat surfaces, with the preparation being dispersed by the rotating sprayer.

Dispersion of liquids by a rotating sprayer is characterised in that dispersed drops are forced not from one point, as is the case with ordinary hydraulic or pneumatic sprayers, but from the entire length of the drop-forming edge represented by the peripheral portion of the spraying element or the sprayer as a whole. With a vertical arrangement of the rotating element, the separation of the preparation drops from its edge will take place in conditions unequal with respect to the flat surface being treated. Drops falling onto the segment AO are separated from the part of the sprayer edge which is located higher than the part of the edge from which the segment OB is treated. This circumstance preconditions non-uniform deposition of the preparation on the surface under treatment. Hence, the diagram of density of preparation distribution on the surface being treated by the proposed apparatus without the screen is asymmetrical in appearance (it is shown by the broken line in Figs. 5, 7, 9, and 10), the ordinates on the segment AO being of greater values as compared with those on the segment OB. Therefore, even a symmetrical diagram of preset density of the preparation distribution on the surface being treated gives a distorted and asymmetrical configuration of the screen, because superimposing a symmetrical on an asymmetrical diagram of preparation distribution in the case of an apparatus without a screen and subsequently determining the difference between their ordinates produces an asymmetrical picture in the left and right parts of the screen.

Besides, the non-uniform character of preparation distribution is largely due to the gravitational forces and resistance of air, which act upon the flying particles of dispersed liquid, distorting their flight trajectories. It is noteworthy that the farther the spraying apparatus is from the surface being treated, the greater the degree of distortion. This factor, too, influences the configuration of the screen edge.

The configuration of the curvilinear edge 8 of the screen 7 ensuring uniform distribution of liquid on the surface being treated and its geometrical dimension are determined experimentally. Initially, it is necessary to construct a diagram of density of liquid distribution on the width of the surface being treated in the case of an apparatus without the screen 7 (shown by the dashed line in Fig. 7). The configuration of the curvilinear edge 8 of the screen 7 must correspond to that of the said diagram (Fig. 8).

In this case the screen 7 with the working surface thereof restricting a portion of the flow area of the window 5 permits screening of the part of the cone of the sprayed liquid passing through the window which, when falling onto the surface being treated, formed a hump on the diagram of liquid (preparation) distribution. Thereby one can achieve uniform distribution of the preparation on the surface being treated, which allows the quality of spraying to be improved and preparation to be economized.

The geometric dimension of the screen is determined on the basis of the scale factor, i.e. the height of the apparatus over the surface being treated and the angle of inclination of the window 5 thereto.

The above-described apparatus operates as follows.

The feeding device 3 forces the working liquid into the central part of the sprayer 1, which is rotated by the motor 2 and which disperses the liquid into fine drops in the form of a circular spray cone, with the drops flying away from the sprayer 1 in trajectories approximating lines tangent to the circumference thereof. Liquid drops whose trajectories are not directed at the surface being treated or extend beyond its limits are screened by the case 4, are deposites on its inner wall, run down to its bottom, and are drained therefrom with the aid of the device 6.

The rest of the dispersed liquid is directed at the window 5 in the wall of the case 4. However, the working surface of the screen 7 restricts a portion of the flow area of the window 5 and, holding back a part of the liquid flowing through the window 5, shapes its spray cone. Owing to the curvilinear configuration of the edge 8 of the screen 7, which limits the flow area of the window 5, the drops settling on the surface being treated produce a diagram of density of preparation distribution preset for the given type of treatment in good time.

Having settled on the inner surface of the screen 7, the drops run down to the bottom of the case 4 to be drained therefrom by the device 6. The screen 7 is movable along the axis of the drive shaft of the motor 2 for the purpose of changing the liquid consumption rate while maintaining the quality of the liquid dispersion and uniformity of distribution of the liquid on the surface being treated.

In the event of several of the spraying apparatuses working in a line (e.g. on a sprayer boom) the flow area of the window 5 is made trapezoidal. In this case the liquid spray cone produced, for example, by the wide-cone sprayer 1 is cut transversely by the inclined edge of the window 5, which gradually reduces the density of the preparation distribution on the periphery of the width of the surface being treated by each device (Fig. 5). This makes it possible to combine apparatuses in a manner ensuring complete uniformity of liquid distribution on the surface being treated.

Given below are examples of different kinds of spraying being done by means of the apparatus, and corresponding removable screens with curvilinear edges.

Fig. 9 is a schematic representation of the apparatus with the screen, side view, ensuring band spraying of plants with herbicides, the latter being directed into the inter-row spaces, keeping off the plant surface.

The diagram of density of the liquid distribution is drawn with the preset spraying conditions duly taken into consideration. The broken line in Figs. 9, 10, and 11 shows the configuration of the diagram of density of preparation distribution, on the surface being treated, which would be obtained from an apparatus without a screen.

Fig. 12 represents a screen with a mirror imaged curvilinear configuration of the edge adequate to that of the diagram of density of preparation (herbicide) distribution on the surface being treated in the event of band spraying of plants. A screen of a similar form may be used to apply different preparations (fertilizers and stimulants) to rows of plants, precluding the possibility of the liquids finding their way into the inter-row spaces.

Fig. 10 is a schematic representation of an apparatus with a screen, side view, for treating (disinfection, treatment with preservatives) small objects moving on a belt conveyer. This movement is characterised in that the centre of the conveyer carries a greater mass than the edges thereof. Therefore, the diagram of density of liquid distribution has a hump in its central part.

Fig. 13 shows a screen with a mirror imaged curvilinear configuration of the edge adequate to that of the diagram of density of liquid distribution on the surface being treated in the event of spraying by means of an apparatus illustrated in Fig. 10.

Fig. 11 is a schematic representation of the proposed apparatus with a screen, intended for work in the inter-row spaces of long-stalk crops which are characterised by non-uniform distribution of leaves throughout the height of the plant. In this case the diagram of density of preparation distribution is drawn with the thickness of leaf surface duly taken into account. The

apparatus has two windows 5 and two removable screens 7 (Fig. 14) with mirror imaged curvilinear configuration of the edges adequate to that of the diagram of density of preparation distribution on the surface being treated in the event of spraying by means of the apparatus represented in Fig. 11.

The above shapes of screens do not cover the whole range of likely types of spraying with different diagrams of density of preparation distribution on the surface being treated; they have been described as individual examples thereof. Given a definite form of the diagram, it is always possible to design and manufacture the removable screen 7 with corresponding configuration of the curvilinear edge.

The apparatus allows treatment of agricultural objects with practically any preset density of distribution of the preparation with respect to the width of the apparatus and the machine as a whole, including uniform distribution of the preparation on the surface being treated. It allows costly preparations to be economized considerably and drastically improves the quality and effectiveness of spraying, which ultimately leads to higher crop capacity. The apparatus can be put to many uses; it is simple in design and reliable in operation.

CLAIMS

1. Liquid spraying apparatus comprising a liquid sprayer to which a liquid is to be fed, the sprayer being enclosed in a case having at least one window through which the spray produced by the sprayer is to escape towards a surface to be treated, a screen-overlapping part of the window and having a curvilinear edge delimiting the active flow area of the window.
2. Apparatus as claimed in claim 1, in which the screen is bent inwards at the said edge.
3. Apparatus as claimed in claim 1 or 2, in which the screen is displaceable transversely of the said edge.
4. Apparatus as claimed in claim 1 to 3, in which the window has a trapezoidal form.
5. Apparatus as claimed in any of claims 1 to 4, in which the sprayer is a rotary sprayer and the window is in a peripheral wall of the case.
6. Apparatus as claimed in any of claims 1 to 5, in which the said edge has a curvilinear configuration which corresponds to the liquid density distribution obtained on the said surface in the absence of the screen, whereby the liquid density distribution obtained with the screen is substantially uniform.
7. Apparatus as claimed in any of claims 1 to 5, in which the said edge has a curvilinear configuration which approximates to the mirror image of a preset liquid density distribution to be obtained on the saidsurface, the said configuration being such that the preset distribution is achieved.
8. Liquid spraying apparatus substantially as described herein with particular reference to any one of the embodiments illustrated in the drawings.

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